Effects of peat and weathered coal on the growth of *Pinus sylvestris* var. *mongolica* seedlings on aeolian sandy soil

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Abstract: The experiment was conducted at the Ganqika Sandy Land Ecological Station in Ke'erqinzuoyihouqi County, Inner Mongolia, in a growing season from April 28 to October 28, 2001. Peat and weathered coal were added to the aeolian sandy soil in different ratios. Two-year-old *Pinus sylvestris* var. *mongolica* seedlings and plastic pots were used in the experiment. The experimental results indicated that: 1) the peat and weathered coal could significantly improve the physical and chemical properties of aeolian sandy soil, and thus promoted the growth of seedlings; 2) the effect of peat on seedling growth, including height, base diameter, root length and biomass, presented an order of 8%>10%>5%>2%>0 in terms of peat contents, and the effect of weathered coal on seedling growth presented an order of 5%>8%>10%>2%>0 in terms of weathered coal contents for height and basal diameter, 5%>8%>2% >10%>0 for root length, and 5%>2%>8% >10%>0 for biomass; 3) the effects of peat were generally greater than that of weathered coal. Meanwhile, 8% peat was the best treatment to promote the growth of *P. sylvestris* var. *mongolica* seedlings.

Keywords: Peat; Weathered coal; Aeolian sandy soil; *Pinus sylvestris* var. *mongolica*; Seedlings; Growth
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Introduction

Pinus sylvestris var. *mongolica* is one of geological varieties of *Pinus sylvestris*, which is naturally distributed along Hulunbeier sandy land and northern Daxin'an Mountains (46°10'N-49°08'N, 118°21'E-122°45'E), (Zeng *et al.* 2002). The tree species has many excellent attributes such as the endurances to drought, barrenness and coldness, so that it has been introduced into most of the provinces of North China and has become one of the major silvicultural tree species in Three-north regions of China. In the last 10 years, the scientists supported by National Natural Science Foundation of China, had carried out many investigations on *P. sylvestris* var. *mongolica* including growth and development, water balance, diameter class distribution, natural thinning, stand density of artificial forests, culture and thinning, protection maturity, stand stability, introduction regionalization, natural regeneration, and so on (Jiao 1989; Guo *et al.* 2001; Zhang *et al.* 2001; Zeng *et al.* 2002).

There are, however, several factors that limit the popularization of *P. sylvestris* var. *mongolica* on the sandy land, for example, low survival rate of silviculture, low rate of natural regeneration under the canopy, low growth rate (especially for seedlings), and low nutrients cycle efficiency (Zeng *et al.* 2002; Wu *et al.* 2002). According to the previous study, soil moisture and fertility are the two primary limiting factors to this species (Wu *et al.* 2002; Zhao 1992). To solve those problems, it is necessary to study the influence of additive fertilizer on the growth of the tree species. Peat and weathered coal are excellent soil ameliorants, moreover. They are the common natural resources of the sandy land area, thus the two ameliorants were used extensively in the agriculture (Meng *et al.* 2000; Song *et al.* 2001), but they are seldom used in the forestry. The objective of this study was, therefore, to investigate the effects of different contents of peat or weathered coal on the growth of the *P. sylvestris* var. *mongolica* seedlings, so as to guide the silvicultural practice of the *P. sylvestris* var. *mongolica* on sandy land.

Materials and methods

Study area

The experiments were conducted at the Ganqika Sandy Land Ecological Station, Shenyang Institute of Applied Ecology, Chinese Academy of Sciences, which is located in the eastern Ke'erqin sandy land, in the Ganqika, Keerqinzuoyihouqi County, Inner Mongolia. The experimental area belongs to dry sub-humid region. Mean annual temperature is about 6 °C and mean annual precipitation is about 450 mm. The altitude of this area is 247.6 m. Major soil types are aeolian sandy soil and meadow soil. The dominant plant species include *Artemisia capillaries* var. *simple*, *A. frigida*, *A. sacrorum*, *Hedysarun fruticosum*, *Caragana microphylla*, *Salix microstachya* var. *bordensis*, *Cleistogenes chinensis*, *Poentilla chinesis*, and *Taraxacum*

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falcilobum. In these years, *P. sylvestris* var. *mongolica* seedlings are planted in large quantities, with the encouragement of the national afforestation/ reforestation policies and sustentation fund.

Properties of soil and experimental materials

Aeolian sandy soil and peat were acquired in local nature resource; and the weathered coal was produced by Huolinhe Humus Acid Factory, Inner Mongolia. The physical and chemical properties of soil and experimental materials were shown in Table 1. The seedlings of *P. sylvestris* var. *mongolica* used to experiment were 2-year-old, planted in local nursery garden. Pots were made of plastic, with 23-cm height, 26-cm top diameter and 16-cm basal diameter.

Table 1. The properties of experimental materials

Materials	pH value	Organic matter /g· kg^{-1}	Total N /g· kg^{-1}	Available N /mg· kg^{-1}	Total P /g· kg^{-1}	Available P /mg· kg^{-1}	Available K /mg· kg^{-1}	Humus acid /g· kg^{-1}
Aeolian sandy soil	8.7	8.90	0.32	33.90	0.42	0.82	52.2	-
Peat	5.5	793.60	22.40	250.8	-	35.8	-	457.80
Weathered coal	6.0	836.50	6.70	-	-	-	-	301.3

The experimental soils were appended different contents of 0 (control), 2%, 5%, 8%, 10% peat; and 0 (control), 2%, 5%, 8%, 10% weathered coals; respectively. The experimental soils, peat and weathered coal were to pass through 1-mm sieve. The mixture of soil and peat or weathered coal was in accordance with the expected content, and then encased into each pot, respectively. Seedlings with similar height, basal diameter, and growth potential were selected as the experimental objects. Four seedlings were planted in each pot. After seedlings were transplanted, each pot was watered to soil saturated point. Three seedlings were kept in each pot after the seedlings had survived. Six replicates were set for each treatment.

Experiment management and analysis methods

The seedlings of *P. sylvestris* var. *mongolica* were transplanted into the pots on April 28, 2001. According to the soil moisture and the growth status of seedlings, the same management such as watering and weeding were conducted on all of the pots.

After one growing season, the soil and the seedling of *P. sylvestris* var. *mongolica* were sampled on October 28, 2001 when the seedling growth had completely stopped. Three 0-20 cm soil cores were sampled in each pot to test the characteristics of soil, and every index value was averaged by the 6 replicates. The chemical characteristics of soil were analyzed with the common methods (Li 1983). Total N was determined by Kjeldahl procedures, organic matter by $K_2Cr_2O_7$-H_2SO_4 method, available N by MgO-Devarda distillation method, the available P by NH_4F-HCl extraction method, the soil K by NaOH melt flamer method, and the water holding capacity of each sample was determined by oven-drying the field-moist soil overnight at 105℃. The seedlings were removed from the pots without any damage to the roots, and then taken back to the lab. The root length, seedling height and basal diameter were measured with vernier caliper after gently removed the soil around the roots. The fresh biomass was weighed with electronic balance, and the dry biomass was weighed after the seedling being oven-dried 48 h at 70 °C. The mean growth indices were obtained in the same content treatment of 15 seedlings.

Results and analysis

Effects of peat and weathered coal on the physical and chemical properties of aeolian sandy soil

Different contents of peat and weathered coal were different in the water holding capacity, pH value and nutrients of the soil (Table 1). With the increasing content, the water holding capacity increased, pH value decreased, and nutrient content increased. In contrast, the effects of the same content peat were higher than that of weathered coal except for soil organic matter content (Table 2).

After peat or weathered coal was applied to the aeolian sandy soil, the soil pH value decreased from a little alkaline to a little acid, and the nourish soil environment was more favorable for the soil animals and microbes to live in, and thus propitious to soil development, therefore, it might eventually provide better microenvironment to satisfy seedling growth.

Effects of peat and weathered coal on seedlings growth

After peat or weathered coal was applied to the aeolian sandy soil, height growth, basal diameter growth, root growth and biomass of the *Pinus sylvestris* var. *mongolica* seedlings were accelerated comparing with that of control (Table 3, Table 4).

As for peat with different contents added to the aerolian soil, preliminarily the effects gradually increased with the increasing contents of peat in the soil, but when the content was higher than 8%, the effects decreased. In conclusion, the effects of different contents of peat on *P. sylvestris* var. *mongolica* seedlings presented an order of 8%>10%>5%>2%>0 for height, base diameter, root length and biomass growth (Fig. 1).

As for weathered coal with different contents added to the aeolian soil, there was the same trend that effects changed from increment to decline with the content increasing. The effects of weathered coal with different contents on the *P. sylvestris* var. *Mongolica* seedlings pre-

sented an order of 5%>8%>10%>2%>0 for height, basal diameter growth, while 5%>8%>2% >10%>0 for root length growth, and 5%>2%>8% >10%>0 for biomass growth (Fig. 2).

Table 2. Physical and chemical characteristics of soils with peat and weathered coals

Treatments	Water holding capacity		pH value		Organic matter	
	Mean /mg· kg^{-1}	Increment (%)	Mean	Decrement (%)	Mean /g· kg^{-1}	Increment (%)
Control	3.5	0	8.7	0	0.89	0
2% peat	4.9	40.0	6.6	24.1	1.61	80.9
5% peat	6.6	88.6	6.5	25.3	2.19	146.1
8% peat	8.3	137.1	6.3	27.6	2.34	162.9
10% peat	9.5	171.4	6.2	28.7	2.52	183.1
2% weathered coal	5.5	57.1	6.9	20.7	1.59	78.9
5% weathered coal	5.9	68.6	6.7	23.0	2.31	159.6
8% weathered coal	6.9	97.1	6.5	25.3	2.56	187.6
10% weathered coal	7.6	117.1	6.4	26.4	2.71	204.5

Treatments	Available N		Available P		Available K	
	Mean /mg· kg^{-1}	Increment (%)	Mean /mg· kg^{-1}	Increment (%)	Mean /mg· kg^{-1}	Increment (%)
Control	33.9	0	0.82	0	52.2	0
2% peat	73.8	117.7	1.69	106.1	101.1	93.7
5% peat	98.5	190.6	2.25	174.4	105.4	101.9
8% peat	113.3	234.2	2.67	225.6	106.3	103.6
10% peat	128.6	279.4	2.74	310.8	112.4	115.3
2% weathered coal	52.5	54.9	0.84	2.4	81.2	55.6
5% weathered coal	54.1	59.6	0.86	4.9	84.5	61.9
8% weathered coal	64.5	90.3	0.89	8.5	96.1	84.1
10% weathered coal	70.1	106.8	0.90	9.8	102.3	96.0

Notes: The water holding capacity of soils was measured at the 24th hour after watering to saturated point respectively on May 15th and June 27th, 2001. The soil samples were taken on October 28th, and the pH value and nutrient content were measured in December.

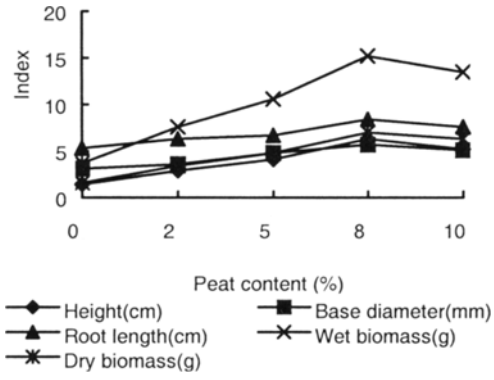

Fig. 1 Effects of peat on annual seedling growth

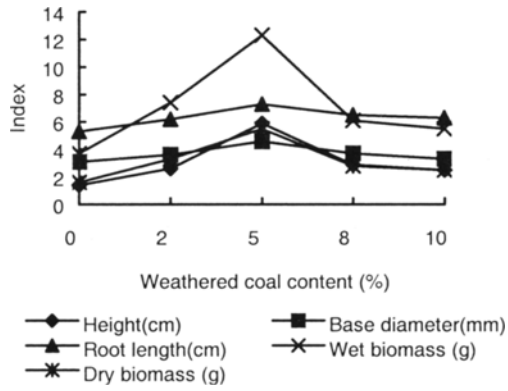

Fig. 2 Effects of weathered coal on seedling growth

Table 3. The impacts of peat and weathered coal on annual seedling growth

Treatments	Height growth		Basal diameter		Root length		Wet biomass		Dry biomass	
	Mean /cm	Increment (%)	Mean /mm	Increment (%)	Mean /cm	Increment (%)	Mean /g	Increment (%)	Mean /g	Increment (%)
Control	1.4	0	3.1	0	5.3	0	3.7	0	1.6	0
2% peat	2.9	107.1	3.6	16.1	6.3	18.9	7.6	105.4	3.4	112.5
5% peat	4.1	192.9	4.8	54.8	6.7	26.4	10.6	186.5	4.8	200.0
8% peat	6.3	350.0	5.7	83.9	8.4	58.5	15.2	310.8	7 0	337.5
10% peat	5.2	271.4	5.1	64.5	7.6	43.4	13.5	265.9	6.3	293.8
2% weathered coal	2.6	85.7	3.6	16.1	6.2	17.0	7.4	100.0	3.3	106.3
5% weathered coal	5.9	321.4	4.6	48 4	7.3	37.7	12.3	232.4	5.5	243.8
8% weathered coal	2.9	107.1	3.7	19.4	6.5	22.6	6.1	64.9	2.8	75.0
10% weathered coal	2.5	78 6	3.3	6.5	6.3	18.9	5.5	48.6	2.5	56.3

Table 4. Variance analysis on seedlings growth

Items	Sources of variance	Sum of squares	Degree of freedom	Mean square	*F*-value
Height growth (cm)	Between groups	349.17	8	43 65	161 67**
	Within groups	34.45	126	0.27	
	Total	383.62	134		
Base diameter (mm)	Between groups	87.77	8	10.97	37.83**
	Within groups	36 94	126	0.29	
	Total	124 71	134		
Root length (cm)	Between groups	81.79	8	10.22	19.65**
	Within groups	65.47	126	0.52	
	Total	147.26	134		
Wet biomass (g)	Between groups	1605.72	8	200.72	81.26**
	Within groups	311.53	126	2 47	
	Total	1917 25	134		
Dry biomass (g)	Between groups	342.45	8	42.81	82.33**
	Within groups	65.54	126	0.52	
	Total	407.99	134		

Notes: **----Significant difference (F=2.66; p<0.01).

Many reports had shown that the higher water and nutrient contents, the better growth of *Pinus sylvestris* var. *mongolica* in sandy soil (Zeng *et al.* 2002; Zhang *et al.* 2001; Zhao 1992; Wu *et al.* 2002: Jiao 1989). So we deduced that there were some toxins that limited the growth of *Pinus sylvestris* var. *mongolica* seedlings (Jin *et al.* 1997; Yazawa *et al.* 2000; Xie 2002). Generally, the effects of peat on the growth of *Pinus sylvestris* var. *mongolica* seedlings were greater than that of weathered coal (Table 3). From the results, 8% peat content was the best treatment to promote the growth of *P. sylvestris* var. *mongolica* seedlings.

Conclusions and discussion

The peat and weathered coal significantly changed the soil physical and chemical properties and increased the soil nutrients and water holding capacity. The effects of peat were greater than those of the same content weathered coal. Although peat and weathered coal promoted the growth of *P. sylvestris* var. *mongolica* seedlings, it was not true that the more quantities, the greater growth. It is necessary that there was a maximum content of peat and weathered coal in aeolion sandy soil respectively. In our study, we found that optimum peat content in the soil was 8%, and the optimum weathered coal content in the soil was 5%; peat was better than weathered coal in terms of the seedling growth effects. Further study should be conducted to answer the questions why the effect of 10% peat content are lower than that of 8% peat, and the effect of 8% and 10% weathered coal content are lower than that of 5% weathered coal content. According to the studies of other scientists, we deduce that there were some inhibitors in the weathered coal and peat (Jin *et al.* 1997; Yazawa *et al.* 2000; Xie 2002). When the inhibitors accumulate enough quantities (e.g., peat content>8%, weathered coal content>5%) in soil, they will not enhance but inhibit the growth of the seedlings.

Since peat is common in the sandy land rural area, and the effect of peat is greater than that of weathered coal for improvements of soil and prompting growth of *P. sylvestris* var. *mongolica* seedlings, and also because the effects of 8% peat content are better than the other peat content, we suggest that 8% peat content could be used as the best fertilization content, which will efficiently promote the growth of *P. sylvestris* var. *mongolica* seedlings in the sandy land.

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References

Guo Yunyi, Yu Jingbo, Lin Hu, *et al.* 2001. Experiment on drought-resistant afforestation with *Pinus sylvestris* var. *mongolica* in west of Ke'erqin sandy land [J]. Inner Mongolia Forestry Sciences & Technology, (3): 11-14. (in Chinese)

Jiao Shuren. 1989. The ecosystem structure and function of sand-fixation forests in Zhanggutai [M]. Shenyang: Liaoning Science & Technology Press, 1-47. (in Chinese).

Jin, F., Nishizaki, Y. and Yamaguchi, T. 1997. Desalination effect of adding peat to an alkali sandy soil [J]. International Peat Journal, **14**(2): 163-165.

Li Youkai. 1983. Common analysis methods in soil agricultural chemistry [M]. Beijing: Science Press, 15-91 (in Chinese).

Meng Xianmin, Ma Xuehui and Cui Baoshan. 2000. Current situation and prospect of peat utilization in agriculture [J]. Research of Agricultural Modernization, **21**(3): 187-191. (in Chinese)

Song Xuan, Zeng Dehui, Tatsuaki Yamaguchi, *et al.* 2001. Effects of peat and weathered coal on activity of rice root system and its nutritional absorption [J]. Chinese Journal of Applied Ecology, **12**(6): 867-870 (in Chinese).

Wu Xiangyun, Liu Guang and Han Hui. 2002. Soil quality in the different types of *Pinus sylvestris* var. *mongolica* man-made sand-fixation forest [J]. Journal of Beihua University (Natural Science edition), **3**(1): 76-79. (in Chinese).

Xie Mingwen. 2002. The mechanism of different content humic acid on the tobacco seedlings growth [J]. Tillage and Cultivation, (2): 23-25 (in Chinese).

Yazawa, Y., Wong, M., Gilkes, R.J., *et al.* 2000. Effect of additions or brown coal and peat on soil solution composition and root growth in acid soil from wheat belt of western Australia [J]. Commun. Soil Sci. Plant Anal., **31**: 743-758.

Zeng Dehui, You Wenshong, Fan Zhiping, *et al.* 2002. Natural regeneration of *Pinus sylvestris* var. *mongolica* plantation on sandy land [J]. Chinese Journal of Applied Ecology, **13**(1): 1-5 (in Chinese).

Zhang Qiuliang and Chang Jinbao 2001. Study on the initial planting density and its adjustment of *Pinus sylvestris* var. *mongolica* artificial forest in the sandy land [J]. Chinese Journal of Eco-Agriculture, **9**(3): 35-37 (in Chinese).

Zhao Wenzhi. 1992. Growth status of *Pinus sylvestris* var. *mongolica* in relation to soil moisture in Naiman sandy land [J]. Journal of Desert Research, **12**(1): 64-70 (in Chinese).